MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

ERT3016 – ROBOTICS
(RE)

2 MARCH 2018
9:00 a.m - 11:00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages including cover page with 5 Questions only. DH-parameter procedures are included in Appendix
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

Question 1

a) What are the differences between the term 'Robot' and the term 'Robotics'?

[4 marks]

b) List 6 important incidents in the history of robotics. Include also the years of the incidents.

[6 marks]

c) Give 5 areas of robot applications and describe how the robots are used in these areas.

[10 marks]

Question 2

Let $F = \{f^1, f^2, f^3\}$ and $M = \{m^1, m^2, m^3\}$ be the fixed and mobile frames for the following homogeneous transformation.

$$T = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 2 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

a) Show how the fixed frame is mapped to the mobile frame with a diagram.

[5 marks]

b) Given $[p]^M = [2, 4, 5]^T$, determine $[p]^F$.

[3 marks]

c) If T_1 and T_2 are screw transformations and $T = T_1 T_2$,

i. Show how T can be achieved with the two transformations T_1 and T_2, using a diagram.

[4 marks]

ii. Determine the matrices T_1 and T_2.

[3+3 marks]

iii. Explain how to determine T^{-1} in words.

[2 marks]

Continued ....

Question 3

Figure 1 is a 4-DOF robot. $J1$ and $J4$ are revolute joints. Meanwhile, $J2$ and $J3$ are prismatic joints.

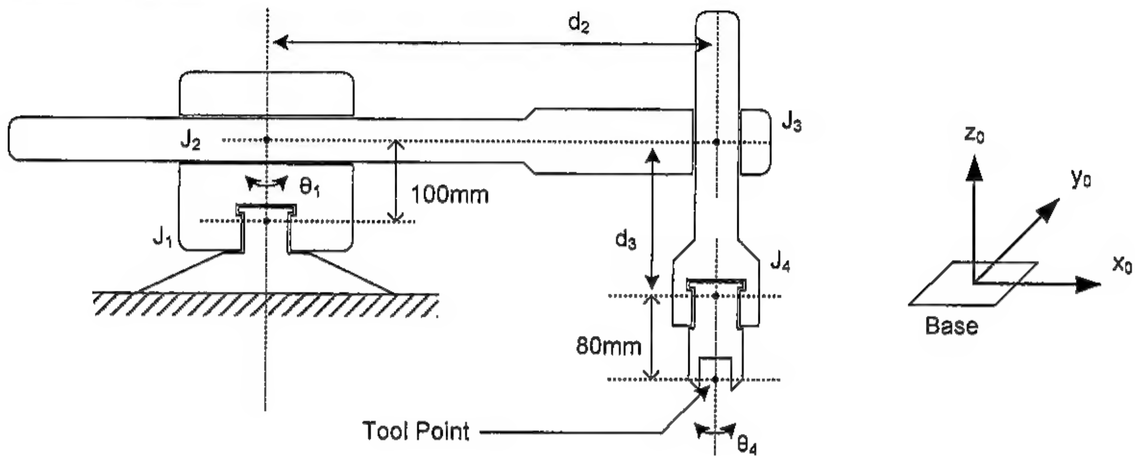

Figure 1

a) Using the base frame in Figure 1, draw the link-coordinate diagram for the robot.

[7 marks]

b) Complete the following table with kinematic parameters of the robot.

Axis	θ	d	a	α	Home
1					$\frac{\pi}{2}$
2					750mm
3					200mm
4					0

[4 marks]

c) Determine the value of arm matrix $T_{base}^{tool}(q)$ when the robot is set to home position.

[9 marks]

Continued ....

Question 4

The following table shows the kinematics parameters of a 3-DOF robot.

Axis	θ	d	a	α
1	q_1	5	0	$-\frac{\pi}{2}$
2	q_2	0	10	$-\frac{\pi}{2}$
3	0	q_3	0	0

a) Determine the general arm equation, $T_0^3(q)$.

[15 marks]

b) Find the joint variables q_1, q_2 and q_3, given that

$$T_0^3(q) = \begin{bmatrix} 0.433 & 0.5 & -0.75 & -13.67 \\ 0.25 & -0.866 & -0.433 & -7.892 \\ -0.866 & 0 & -0.5 & -15.66 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[5 marks]

Continued ....

Question 5

Figure 2 shows the top view of a robotic workstation with two wooden rectangular blocks resting at different coordinates. Block A and Block B have the heights of $8cm$ and $3cm$, respectively. The robotic arm is operated to pick Block A and place on top of Block B, with alignment on the centroids and the major axes. While moving Block A, there must be a distance of $15cm$ between the workstation and the bottom surface of the moving block. Assume the robot grasps the block in the middle of the long sides.

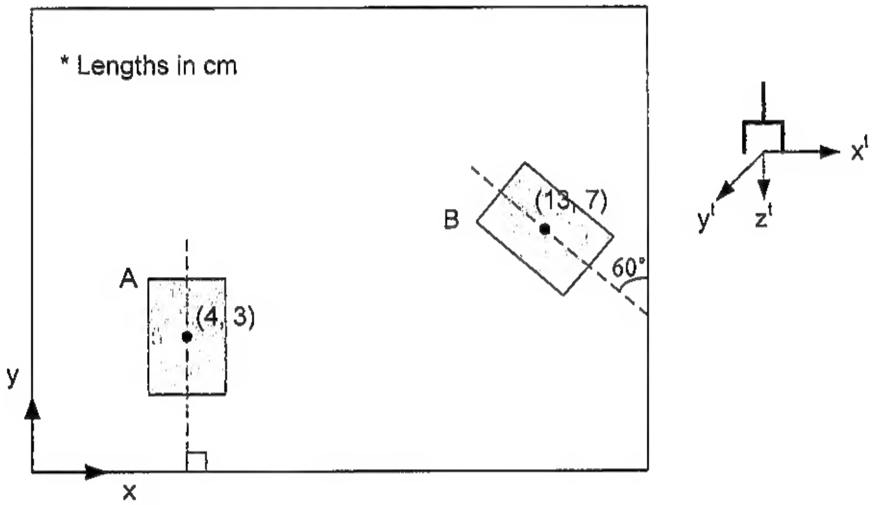

Figure 2

a) Determine the arm matrix value T_{base}^{pick}

[4 marks]

b) Determine the arm matrix value $T_{base}^{lift-off}$

[4 marks]

c) Determine the arm matrix value T_{base}^{place}

[4 marks]

d) When moving Block A from lift-off point to set-down point, the second joint of the robot goes from 30° to 158°. The motion takes 4 seconds. If the trajectory is done using a third-order polynomial, determine the joint angle, velocity and acceleration at time 2 seconds.

[8 marks]

Continued ....

Appendix

Procedure to DH-Parameter

1. Number the joints from 1 to n starting at the base and ending with the tool yaw, pitch and roll, in that order.
2. Assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Set $k = 1$.
3. Align z^k with the axis of joint $k + 1$.
4. Locate the origin of L_k at the intersection of the z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}.
5. Select x^k to be orthogonal to both z^k and z^{k-1}. If z^k and z^{k-1} are parallel, point x^k away from z^{k-1}.
6. Select y^k to form right-handed orthonormal coordinate frame L_k and set $k = k+1$. If $k<n$, go to step 3; else continue.
7. Set the origin of L_n at the tool tip. Align z^n with the approach vector, y^n with the sliding vector
and x^n with the normal vector of the tool. Set $k = 1$.
8. Locate point b^k at the intersection of the x^k and z^{k-1} axes. If they do not intersect, use the intersection of x^k with a common normal between x^k and z^{k-1}.
9. Compute θ_k as the angle of rotation from x^{k-1} to x^k measured about z^{k-1}.
10. Compute d_k as the distance from the origin of frame L_{k-1} to point b^k measured along z^{k-1}.
11. Compute a_k as the distance from the point b^k to the origin of frame L_k measured along x^k.
12. Compute α_k as the angle of rotation from z^{k-1} to z^k measured about x^k.
13. Set $k = k+1$. If $k \leq n$, go to step 8; else stop.

Generic DH-Transformation Matrix

$$T_{k-1}^{k} = \begin{bmatrix} C\theta_k & -S\theta_k C\alpha_k & S\theta_k S\alpha_k & a_k C\theta_k \\ S\theta_k & C\theta_k C\alpha_k & -C\theta_k S\alpha_k & a_k S\theta_k \\ 0 & S\alpha_k & C\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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